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Integration of Logistics and Engineering Development Tasks

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Abstract

Most current development contracts contain separate requirements for accomplishment of logistics and engineering analyses. In many cases these analyses are interrelated, and accomplishment of one may be dependent on the prior completion of another. Not all engineering analyses have direct impact on acquisition logistics, but many, including most reliability and maintainability (R&M) analyses, are significant factors in determining logistics support requirements. Additionally, the results of logistics analyses should be used in selection of design solutions. Poor planning and lack of understanding of the interrelationship of engineering and logistics can lead to inefficient use of resources and lost opportunities to improve the supportability of the equipment under development.

Using experience gained by the authors in both engineering and acquisition logistics, this paper will attempt to demonstrate the need for integration of logistics and engineering development planning. The need for early determination of analysis responsibilities and schedules will be discussed, and a sample of an integrated approach to logistics and engineering will be presented. Integration of developmental engineering and logistics analysis efforts required by MIL-STD-785B "Reliability Program for Systems and Equipment", MIL-STD-470A "Maintainability Program Requirement for Systems and Equipment", and MIL-STD-1388-1A "Logistics Support Analysis" will be the primary topics. Also discussed will be the advantages of a common computer for accomplishment and storage of both engineering and logistics analysis.

Types of engineering analysis covered will be R&M allocation, prediction and measurement, Failure Modes, Effects and Criticality Analysis (FMECA), Built-In-Test (BIT) effectiveness, and availability/operational effectiveness modeling. Covered from the logistics side will be Repair Level Analysis, maintenance task analysis, Reliability Centered Maintenance, spares and support equipment quantity determination, and Life Cycle Cost analysis of design alternatives.

OVERVIEW

Department of Defense (DoD) acquisition initiatives in recent years have increasingly highlighted supportability engineering as a design discipline capable of significantly increasing the amount of time that a system is available for operational use. The Air Force development community has responded to these DoD initiatives for improving system reliability and maintainability (R&M) by increasing the emphasis on the systems engineering process as part of the product division acquisition efforts within the Air Force Systems Command (AFSC). Simultaneous efforts by the acquisition logistics community have been aimed at predicting the support resources likely to be consumed by a given design in order to influence the selection of design alternatives and support structure alternatives that will result in the lowest system life cycle costs. The Air Force logistics community has responded to DoD developed standards for logistics support analysis by assigning a Deputy Program Manager for Logistics (DPML) and a staff of logistics specialists as part of the product division acquisition efforts within AFSC.

Acquisition logistics programs are generally structured to comply with the planning and analytical framework provided in MIL-STD-1388-1, Logistics Support Analysis (LSA) and MIL-STD-1388-2, DoD Requirements for a Logistics Support Analysis Record (LSAR), both developed in response to DoD Directive 5000.39, Acquisition and management of Integrated Logistics Support for Systems and Equipment. R&M engineering programs are generally structured to comply with MIL-STD-785B, Reliability Program Requirements for Systems and Equipment, and MIL-STD-470A, Maintainability Program Requirements for Systems and Equipment. A primary goal of the DoD standards is to provide a structure that standardizes the conventions and methods used to evaluate design characteristics that most influence the availability and the life cycle cost of a system. Standardization, in turn, permits quantitative comparisons across systems in the form of cost/benefit analysis and "trade studies" that facilitate design decisions.

Although, intuitive to many in concept, application of developmental supportability engineering and logistics analytical conventions to influence system design during development is inherently difficult. The ability to predict the support requirements likely to result from a particular set of design characteristics is limited significantly by design immaturity and the lack of available performance data from similar systems operated in similar environments. As the design matures, developmental test and analysis efforts logically generate increasingly more accurate system performance data, and permit correspondingly more accurate predictions about the availability and life cycle cost of the final product. However, as the design matures, changes logically become more and more expensive to effect. Cost ceilings and schedule constraints increasingly limit design flexibility and the probability increases that an opportunity to significantly improve system availability or decrease life cycle support costs might be lost.

Compounding the negative effects of competing design constraints on the ultimate availability and life cycle support cost of a fielded system are the arguably more manageable problems associated with integrating the independent efforts of the supportability engineers and the logisticians in the corporate work setting. Each discipline has developed its own dialect, unique data bases, internal procedures and schedules that hinder or preclude symbiotic progress toward ultimately identical goals. Lack of institutional interfaces between logistics and engineering functions and incomplete corporate level understanding of the two processes lead to ineffective up-front planning and

result in inefficient use of resources and lost opportunities.

The authors will describe an integrative thought process, derived from their experience in both engineering and acquisition logistics, that attempts to demonstrate how the engineering and logistics analytical processes can each benefit from the other. We will discuss the iterative nature of the development process and how proper sequencing of analytic efforts is critical to efficiency and eventual effectiveness. We will discuss the advantages of a common computer data base for accomplishing and storing engineering and logistics analysis. Finally, we will discuss the value of post-production analysis in assessing the effectiveness of up-front planning and the accuracy of estimating methodologies in predicting the availability and support cost impacts of early design decisions.

Integrative Logistics/Engineering Process

System-level design parameters that require minimization of support resource consumption and maximization of operational availability should be established in the earliest stages of the programs. Examples of these types of requirements are:

Reliability
Maintainability
Minimization/Elimination of Support Equipment
Minimize/Standardize Part Types
Facilitate Two-Level Maintenance
  - 100% On-Aircraft Fault Isolation to
    Lowest Recoverable Unit
Minimize Life Cycle Cost

Utilization of this "performance-based" concept allows the developer the flexibility to optimize the system within the constraints of the customer's functional requirements without imposing unnecessarily detailed design requirements. The system developer then has the responsibility to allocate the system level requirements to the lowest recoverable unit level based on the best available data.

As the hardware design takes shape, the systems engineers and logisticians must take the available design data and predict the capability of the design to meet the performance requirements. Typically, the engineers conduct iterative reliability, maintainability and availability analyses, while the logisticians predict life cycle cost, spares quantities and optimum repair level. The results of these analyses must then be compared to system-level requirements and to the individual unit's allocated requirements.

A rank order list of units which are driving performance or support costs to unacceptable levels should be prepared and passed on to the design groups. The design of these items should then be examined to ensure that all practical means have been taken to achieve the units allocated requirements. If the unit can not reasonably be expected to achieve it's allocated requirements, the system-level performance concept allows the developer flexibility to re-allocate among the components of the system (i.e.; a system which was exceeding its allocated requirement may have its allocation raised in order to lower the allocation of a system not achieving it's requirement).

Major system component vendors should be included in the allocation process. Allocations to vendor components should be flowed-down to the vendor's specification. Warranties and incentives should be considered to ensure performance that meets minimum requirements. The vendors must also be required to provide the necessary data to the system developer to support system analysis.

Data elements required to support this process include:

Reliability
  Mean Time Between Maintenance (MTBM)
  Mean Time Between Removal (MTBR)
  Mean Time Between Failure (MTBF)

Maintainability

  Mean Time to Repair (MTTR)
  Maintenance ManHours per Flying Hour
    (MMH/FH)

Cost
  Support Equipment Cost
  Spares Cost
  Facilities Cost

Turn-Around Time
  Transportation
  Packaging
  Shipping
  Repairing

Iterative Analysis Process

The system developer must be responsible for accomplishment of all analyses to demonstrate compliance with the supportability requirements. These analyses typically include:

Engineering	Logistics
Operational Effectiveness Modeling (Availability)	Repair Level Analysis
R&M Allocation & Predictions	Reliability Centered Maintenance
Failure Modes, Effects & Criticality Analysis	Provisioning
Support Equipment Requirements	Fault Isolation Procedures
Preliminary & Final Design	Manpower Levels

Many of these analyses have multiple purposes. For example, Failure Modes, Effects and Criticality Analysis (FMECA) is used by engineering to evaluate the design for its fault tolerance and to demonstrate compliance with flying safety requirements. FMECA is required by logistics to identify failure modes which will require subsequent fault isolation and repair procedures. Engineering is generally the only agency with adequate knowledge of the system design to prepare a FMECA. However if engineering prepared the FMECA only to satisfy their own requirements, significant data required to support logistics efforts would be not be generated. Similarly, operational effectiveness models generated by engineering will be dependent on the logistics support concept, and therefore plans must be made by logistics to provide engineering with their planned maintenance concept and manpower, turnaround times, repair level, spares requirements, etc.

Thus, to increase the effectiveness of the developmental supportability efforts, engineering and logistics must jointly identify their data requirements and need dates. It must be assumed from the outset that these efforts will be iterative. Both organizations must plan to update their analyses with new, increasingly detailed and accurate information.

Detailed Data Requirements

Typically, logistics support analysis will require the following information from engineering:

Reliability Data
    Comparative Analysis
    Analytical Prediction (MIL-HDBK-217)
    Test Results

Maintainability Data
    Failure Modes
    Diagnostics Method (BIT, SE, or manual)
    Physical Configuration

Usage Data (Operating time versus calendar time)

Support Equipment Requirements
    Common
    Peculiar
    Quantities

Engineering Drawing Data
    Accessibility

Engineering will look to logistics for guidance in selection of design alternatives. In many cases there are several acceptable design alternatives from a functional standpoint, in these instances logistics can impact the design by providing analyses to rank the alternatives in terms of support cost. Also, some design alternatives, which meet all performance requirements, may be completely unacceptable to the logistics community because of large life cycle support costs associated with supporting the design.

Sequence of Information Flow

The timing of data flow will be essential to optimizing the system's performance. Data must flow to the support community in time for them to analyze it and flow back their results to the design engineers before it is too late to make cost effective changes. The need for detailed data must be balanced against its availability. In most cases, analysis must be begun with preliminary, "high-level" data, then be refined as the design matures. A typical sequence of events would be as follows:

1) Engineering must estimate performance of the preliminary design, both at the system level and the major component level (Line Replaceable Unit (LRU). These estimates would include reliability, maintainability, diagnostic method, etc.

2) These estimates would be used by logistics to estimate the life cycle cost of supporting the system and used bye engineering to assess the design compliance with operational effectiveness requirements. The major system components should then be ranked by negative impact to support cost and operational effectiveness.

3) Engineering should then respond to the drivers by searching for design alternatives or enhancements that will reduce support costs or enhance operational effectiveness without severely impacting performance or schedule.

4) When the alternatives have been identified, both engineering and logistics should conduct a detailed cost/benefit analysis to arrive at the optimum design solution.

5) The selected design/support concept should then be finalized. The objective for completion of this initial round of trade studies should be Preliminary Design Review (PDR).

6) Following PDR the selected system design and support concept can be analyzed in greater detail. The operational effectiveness and support cost models should be continuously refined as the design becomes more and more mature. The logistics support concept should also be reevaluated as the design matures.

7) At CDR, the hardware design should be complete. The support cost and operational effectiveness models should reflect the current design. All data should be available to provide estimates of system performance against requirements. Beyond this point, the practicality of changing the design to reduce support costs or improve availability diminishes.

8) Following CDR, test results should be used to validate the predictions used in the models. Proposed spare quantities, numbers of support equipment and manpower allocations may still be changed, but design impact will be unlikely.

It is obvious to anyone who has been involved in the development of a complex system that the cost of changing the design increases exponentially as the development process continues. Therefore, the logistics and supportability engineering communities must be prepared to evaluate the design as efficiently and quickly as possible. A well-trained, prepared group of engineers and logisticians is most valuable early in the program. Prepared with the right analytical tools, a small group can have an effective input to the preliminary design. Unfortunately, engineering and logistics traditionally do not effectively exchange information. This results in inefficiencies and delays accomplishment of the objectives of a design optimized for supportability.

Shared DataBase

A shared database can be used to improve the communication between the engineering and logistics communities. At the beginning of the development effort, both logistics and engineering should define the efforts which will require an exchange of information. All required data elements required to support the efforts should also be identified and defined.

Based on this list of data elements, a common database should be created. This database should be accessible to the both the people who generate the information as well those who will use it. This can be effectively accomplished via a distributed computer network with centralized data storage.

Currently, many companies depend on a paper communication system. For example, FMECAs are generated by engineering using some type of automated system and then distributed by hard-copy to all users. Much of the information contained in a FMECA can be transferred directly to the Logistics Support Analysis Record (LSAR) required on many current programs. In many cases, because no planning was done to ensure that data systems were compatible, this data must be re-keyed by logistics personnel from the hard copy into the computer system used to generate the LSAR.

An additional communication problem can be created when logistics receives source data from other organi-

zations that, because of definitional differences, cannot be used directly. This may cause an analyst to make an adjustment to a value that could have been directly transferred if definitions had been determined jointly. (How many different definitions of MTBF exist?) Again, joint development of the parameters to be used and their definitions could have reduced the manpower required to complete the analysis.

Database incompatibility robs manpower that could be used for much more effective purposes. When beginning a development effort, planning and preparation are required to ensure that resources are utilized effectively. There are three major supportability functions occurring simultaneously, yet often independently, in every development program. These three functions must be integrated such that information flow is enhanced, not impeded. The three functions are as follows:

1) Reliability & Maintainability Engineering

   Allocations
   Predictions
   FMECA
   Diagnostics
   Operational Effectiveness Modeling

2) MIL-STD-1388 Logistics Support Analysis

   RLA
   Provisioning
   Maintenance Task Analysis

3) Life Cycle Cost Analysis

All three of these functions are simultaneously generating and using information. This information flow must be understood, planned and prepared for to avoid needless duplication of effort. The support analysis effort must be accomplished in a timely manner if the design impact discussed previously is to take place.

The integration we propose is not something that requires a state-of-the-art computer system, or the arrival of some long-awaited break through in data standardization. Current computer technology in place at most companies should easily enable the automated transfer of most data.

This situation can become more complicated when different groups are using different parameters for the same quantity, or have different definitions for the same parameter. This can all be avoided by requiring a common database, common parameters, and common definitions for those parameters. In this manner, when the reliability engineer enters the latest prediction for any component of the system it is automatically entered in the LCC analysis, the LSAR, the FMECA, the RLA, etc.

This same integrative concept should be applied to vendor/subcontractor supplied information. Specifying that the work be done in accordance with a military standard does not guarantee that the data provided will be in a standard format or be accomplished using similar methods. In order to ensure a quick, painless integration of the vendor data into the prime's data system, the vendor should be brought on the team. Data will always be required in hardcopy. However if the vendor is instructed to do so, the vendor data can easily be made available on computer media also, and may be easily uploaded to the prime's computer database.

For example, most companies' reliability predictions are created and stored in some type of computer database. These reliability figures are then required to support virtually every other supportability analysis effort, such as LCC analysis, LSAR, RCM, RLA, and any operational effectiveness models, most of which are also computerized. In most cases the reliability predictions will be manually reentered into most of these other computerized analysis systems. Because of the large amount of manual effort required, the users of this reliability data are not anxious to update their analyses as more current reliability predictions become available.

One method to accomplish the transfer of this data among the users would be to require each organization to use a common computer and common database system (i.e. ORACLE, INGRES, etc.) for their analysis. If all analysis systems are linked on a single computer systems, then all analyses can be immediately updated when any single data element in the system is changed.

Although this may be the simplest solution, it is probably the least practical. Generally, each analysis is already being accomplished via some specialized program. These programs may be running on everything from PC's to mainframes. However, most programs can create and read straight alphanumeric data (ASCII). If the parameters to be exchanged are jointly defined, and input/output file formats are known, data can be shared via magnetic tape, floppy disk, etc. With this arrangement, data can be shared at specific points, either calendar time intervals (i.e.; weekly, monthly, etc) or on an event based schedule (PDR, CDR, LSA Review, etc.).

It is impossible to define one method that will work at every site, but the important thing is to plan for the data transfer. Determine the primary elements of data that must be transferred from group to group, and rank them based on the negative impact of having to transfer the data manually. Then evaluate the time and effort required to automate the transfer of the information. In this manner the automation process can be prioritized based on the impact.

Conclusion

The process of influencing design to minimize support cost and maximize operational effectiveness is highly dependent on the flow of information between organizations. Without the timely flow of data between engineering and logistics the desired design influence cannot be obtained. In the first stages of the program, engineering and logistics must identify and define the data elements that will flow between the two organizations. Then the method which will be used to efficiently transfer this data must be chosen. Finally a schedule identifying which data is required to support intermediate program milestones must be arrived at jointly.

Properly planned and implemented, a supportability analysis program combining both engineering and logistics can have a tremendous, positive impact on the supportability of the fielded product. With supportability analysis integrated with design, the operational weapon system has a greater probability of meeting its operational effectiveness requirements at lowest possible support cost.

Author Information

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Major Thomas P Toole is chief of the C-17 SPO's logistics engineering branch and is responsible for management of Logistics Support Analysis, Reliability Centered Maintenance, Repair Level Analysis and Life Cycle Cost analysis. Major Toole was assigned to this position in October 1988 following completion of a Master of Science in Logistics Management at the Air Force Institute of Technology. Major Toole received his undergraduate degree at the Air Force Academy in 1977 and was an aircraft maintenance officer prior to his assignment to AFIT.